Space Technology Research Grants

Continuum-Kinetic Hybrid Framework for Chemically Reacting Flows

Completed Technology Project (2015 - 2019)

Project Introduction

Predictive modeling of chemically reacting flows is essential for the design and optimization of future hypersonic vehicles. During atmospheric re-entry, complex flow structures form around the vehicle surface, exciting the gas molecules and causing chemical reactions. This work seeks to develop a multi-scale model for chemically reacting gas mixtures, which would have an immediate impact on applications involving entry, descent, and land (EDL) and thermal protection system (TPS) design. Simulation of these flow structures use hybrid approaches which model the gas differently according spatial region considered. Far from the vehicle surface, the gas flows are smooth, or equilibrium, and can be modeled using continuum fluid equations. Closer to the vehicle surface, the flows become more complex and are called non-equilibrium. This region is modeled using statistical techniques that track gas molecules individually. At the vehicle surface, it is also desirable to simulate the interactions of the gas molecules with the solid surface. These types of interactions are dependent on the microscopic characteristics of molecules and are simulated in molecular dynamics software. Understanding the nature of the gas flow in these three regions is key to characterizing the behavior of the gas around the vehicle. Previous research has successfully interfaced these three domains. However, these studies have not considered gases which could undergo chemical reactions. The goal of this work is to understand how the chemical reactions change the nature of the gas flow. To do this, a consistent treatment of chemistry models in each region will be investigated, as well as a rigorous coupling between the solutions in each region. From there, the effect of chemically reacting gas mixtures on the vehicle surface can be ascertained. This work will not deliver original software, but will provide a framework enabling these kinds of studies. There are many software packages available conducting simulations, which will be modified in this work. NASA in particular has been a pioneer in developing software for studying complex gas flows. Several NASA packages such as DPLR (Data Parallel Line Relaxation), LAURA (Langley Aerothermodynamic Upwind Relaxation Algorithm), and MAP (Multiphysics Algorithm with Particles) are being considered for use in this work.

Anticipated Benefits

This work seeks to develop a multi-scale model for chemically reacting gas mixtures, which would have an immediate impact on applications involving entry, descent, and land (EDL) and thermal protection system (TPS) design.

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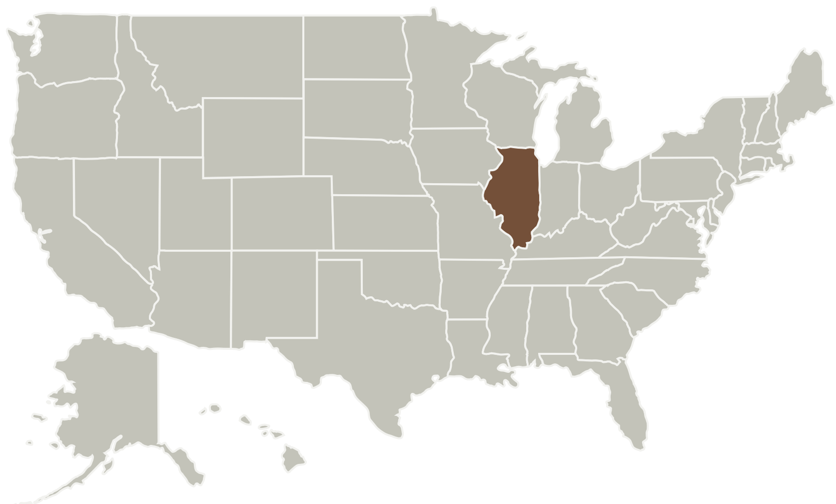
Table of Contents

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Illinois at Urbana-Champaign	Lead Organization	Academia	Urbana, Illinois

Primary U.S. Work Locations
Illinois

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Illinois at Urbana-Champaign

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Kelly Stephani

Co-Investigator:

Taiyo Wilson

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**

1 2 3 4 5 6 7 8 9

Applied Research | Development | Demo & Test

Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  └ TX09.4 Vehicle Systems
    └ TX09.4.5 Modeling and Simulation for EDL

Target Destination

Foundational Knowledge